MATERIALS AND METHODS

Multisensor capacitance probes were calibrated and the accuracy of soil water measurements verified gravimetrically and with TDR sensors under greenhouse conditions at the Texas Agricultural Experiment Station, Lubbock. Samples of an Olton soil were collected from the plowed surface Ap horizon, (0–0.15 m) and calcic (1.5–2.0 m) soil horizon. Surface soil characteristics determined in an earlier study were 270 g kg^{-1} clay, 480 g kg^{-1} sand, and an electrical conductivity (EC) of 1.08 dS m^{-1}, while the calcic layer had 300 g kg^{-1} $CaCO_3$, 135 g kg^{-1} clay, 480 g kg^{-1} sand, and an EC of 0.50 dS m^{-1} (Baumhardt and Lascano, 1993). Each soil material was collected, passed through a 12-mm hardware cloth screen, air-dried in a greenhouse, and packed into triplicate columns (six columns total).

Soil Column Preparation

Soil column containers were made from 1.02 m tall by 0.5 m diameter 120-L plastic barrels by removing the tapered upper 0.26 m and installing a 12-mm-o.d. hose barb in the bottom for water addition. By wetting the soil columns from the bottom, air entrapment and uneven water distribution were avoided. Washed and air-dried coarse gravel with a mean diameter >12 mm was placed into the tapered bottom to a depth of 0.26 m at the same time that MCAP access tubes were positioned near the soil column center. The gravel was covered by a 0.5-m-diam. nylon window screen disk and cheesecloth to reduce soil sifting into and mixing with gravel during soil column preparation. Plastic barrels, nylon window screen, and cheesecloth materials were used to avoid potential interference with electrical soil water content sensors. The barrel above the gravel was a nearly cylindrical column 0.5 m tall and 0.5 m in diameter (Fig. 1) with a volume of ≈93 L (92.75 L as measured using water). All six soil columns were packed in 0.10-m increments above the gravel to an overall average density of 1.40 Mg m^{-3} with a standard deviation (SD) of ±0.02 Mg m^{-3} for the three surface soil columns and 1.39 ± 0.04 Mg m^{-3} for the three calcic soil columns.

Instrumentation to measure θ_v was installed during soil column preparation. The MCAP access tubes were positioned near the center of the soil column, while TDR sensors were installed equidistant from the soil column wall and MCAP access tube (Fig. 1, TOP). Sensors of the MCAP array (EnviroScan) were positioned at depths of 0.1, 0.2, 0.3, and 0.4 m; and 0.2-m trifilar TDR probes (TR-100, Dynamax, Houston, TX) were placed horizontally at depths of 0.05, 0.15, 0.25, 0.35, and 0.45 m (Fig. 1). Vertical and horizontal separation between MCAP and TDR sensors was ≈5 cm to avoid potential interference. In each soil column, temperatures at 0.05-, 0.1-, and 0.3-m depths were measured on the side opposite of the TDR probes and 0.1 m from the soil column wall using copper-constantan thermocouples mounted on 1-cm-square 0.45-m-long wood stakes.

Measurements

Measurements included soil temperature, θ_v, and the amount of water added to each soil column. Soil temperature was measured every 15 s with sealed thermocouples made from twisted and soldered 22-ga Cu-Constantan wire (Omega Engineering, Stamford, CT) averaged and electronically recorded every 10 min using a CR-10 data logger (Campbell Scientific, Logan, UT). Using automated data collection systems, the soil water content was determined from F_s measurements recorded every 2 min during initial water additions for calibration data, and then every 10 min after wetting. The

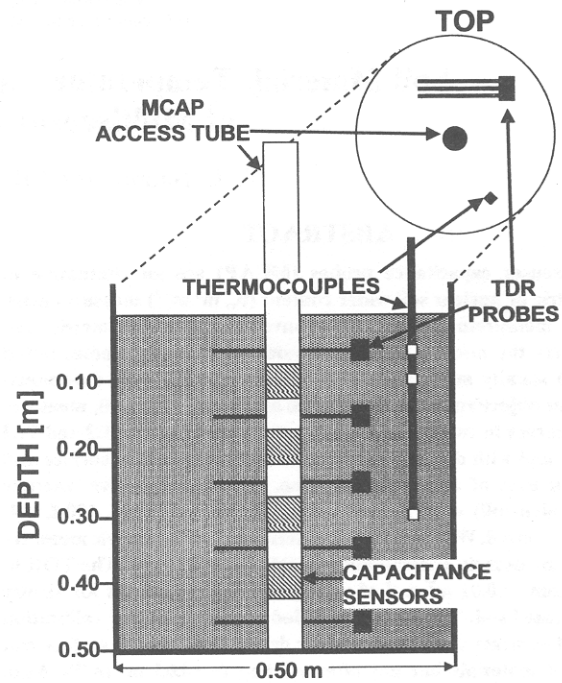

Fig. 1. Diagram (not-to-scale) showing the relative position of soil temperature and water content sensors in each soil column. Thermocouples measured soil temperature 0.05, 0.1, and 0.3 m below the surface. Soil water content was measured in 0.1-m intervals beginning at the 0.05-m depth for time domain reflectometry (TDR) wave guides and 0.1-m depth for multisensor capacitance probe (MCAP) sensors with a lateral separation of 0.05 m to minimize potential interference.

TDR probes were connected to a cable tester (model 1502C, Tektronix, Beaverton, OR) through multiplexers (model TR-200, Dynamax), which were controlled by a laptop computer running the TACQ software (Evett, 1998). The equation of Topp et al. (1980) was used to relate apparent permittivity to water content. Values for F_a and F_w in Eq. [1] were determined for the MCAP sensors according to the recommended factory procedures in air and in a water bath using local tap water (EC of 1.30 dS m^{-1}). Water added to soil columns from the constant head Marriott system was measured to obtain a mean θ_v for the soil column using an electronically recorded balance (Mettler PM34, Mettler-Toledo, Greifensee, Switzerland).

Experimental

Our experiment proceeded in four steps that included measurement of soil water content gravimetrically and by the TDR or MCAP systems with collateral measurement of soil temperature. First, the volumetric water content of the air-dry soil was determined from the gravimetric water content of the soils used for packing and the mean bulk densities of the packed soil columns. The soil columns were sealed with 0.0254-mm plastic bags, and measurements of soil temperature and air-dry water content using TDR and MCAP sensors were made during day of year (DOY) 89 to 125 in 1997. Second, for calibration, θ_v with depth was measured by TDR and MCAP sensors from DOY 126 to 136 while adding water (EC of 1.30 dS m^{-1}) from a constant head supply (0.5 m above the soil surface) through the bottom inlet of the column. Soil water content measured using TDR was regressed on the calculated scaled frequency, Eq. [1], using nonlinear fitting methods (SAS Institute, 1988). Third, the near-saturated θ_v (MCAP and TDR) and soil temperature were measured for resealed soil